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IMPROVING THE QUALITY OF SERVICES BY SCHEDULING ALGORITHMS IN WIMAX NETWORKS

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ABSTRACT

In the past years, wireless communication is developed considerably. Also, like WiMAX network, broadband wireless networks are also taken into attention. In these networks, Quality of Services (QoS) is used for various Application support. These programs include internet telephone, multi-media services such as video broadcast, video conference and etc. Providing the quality of service is complex in a multi-service WiMAX environment as it data flow, traffic behaviors and quality requirements have different services. It is possible that a unique scheduling algorithm is not adequate due to the features of distinct quality of service of each service. Thus, selecting a suitable scheduling algorithm is important in providing the quality of service of these broadband wireless access networks. The present study conducted a comprehensive study about Point-to-multiPoint scheduling algorithms in WiMAX networks. A detailed simulation was performed to investigate the efficiency of the main scheduling algorithms as FIFO, WFQ, PQ and MDRR and the performance of each scheduler is evaluated to support the various classes of quality of service and various applications. The results of simulations showed that appropriate selection of scheduling algorithm can improve the required quality of service for different traffic types of users. The best scheduling algorithm in this evaluation is determined based on the minimum jitter, throughput and maximum received traffic for each servicing class and specific Application.

KEYWORDS: IEEE 802.16, Quality of Service, Scheduling, OPNET

Wi MAX is short form of Worldwide Interoperability for Microwave Access. This technology provides access to broadband wireless data in long distances. This technology is based on electronic and electricity engineers' association standard (IEE802.16) providing basic internet protocol link to the user. Different types of IP protocol based applications are increased considerably in recent years. Various multi-media applications with e-mail applications, file transmission and web browser are becoming famous increasingly. These applications send big voice and image flows with bandwidth requirements and various delays and this leads to heterogeneous traffic load in the network. Any application needs a specific type of services quality. IEEE 802.16 is designed to achieve some goals as easy development and establishment, high data rate, extended covered area and wide frequencyspectrum. This standard can provide the quality of service for all various types of applications including real-time traffic based on the type of flow.

Despite the fact that various scheduling algorithms are presented for WiMAXnetworks, there is no comprehensive study to provide integrated software to compare these algorithms. The present study aimed to create a complete perception of relative performance of algorithms and scheduling plans and using the results to consider its deficit in efficient models design. The present study focused on implementation of sample algorithms for uplink and downlink traffic by OPNET. Also, it attempted to evaluate the algorithms by traffic models that are designed specifically for WiMAXto show various applications supported in this technology. It is as we can observe by including the obligatory parameters and some optional parameters in all traffic classes in IEEE 802.16-2005.

The present study showed that none of the current algorithms have required ability to create an efficient, strong and fair scheduler to support all WiMAXclasses. The analysis of this study can be used to perceive the strengths and weaknesses of current scheduling algorithms and the efficient scheduling algorithms considering all or some of the weaknesses. This paper is organized as follows: In Section 2 we start with some related work. In Section 3 we describe the quality of services and its components and suitable servicing classes with scheduling algorithms. In Section 4, different scheduling algorithms in WiMAX network were defined. Then, in section 5, we explain simulation model and some discussions regarding the results are

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presented. Finally, Section 6 concludes the discussion and presents our future work.

RELATE WORKS

In recent years, many researchers considered services quality and application of various methods to improve it including scheduling algorithms, admission control methods, interlayer combinations and etc. Some related works are explained in this section. [1] Refers to explanation of key issues and effective factors in design of scheduling methods by considering channel various methods. Here, scheduling goal is optimal application of resources and assurance of quality of services, maximum throughput and energy consumption minimization. Article [2] investigated suitable services quality classes for each application and it defines the best servicing class for a mobile user. Also, [3] investigated services quality integration solutions in heterogeneous networks of WLAN and WiMAX by two integration modules GVLL and MIH. Various scheduling algorithms as DWRR, WFQ and FIFO are investigated by OPNET simulator and the results based on the services quality of each class are defined but the type of traffic in a network is not defined. The two level scheduling (TLS) in [5] is presented to support the services quality and fairness in downlink traffic of WiMAX. The study stated that its proposed algorithm reached better results of WRR and RR algorithms. The study [6] conducted a comprehensive study of scheduling algorithms efficiency in point- to-multipoint WiMAX based on OFDM. Some algorithms are investigated than can support multiple service classes, guaranteeing the quality of services and fairness among servicing classes and bandwidth application.

QUALITY OF SERVICES

Generally, there are two comprehensive definitions of services quality [7]:

- User-based services quality: It is comprehensive effect of services efficiency determining the satisfaction of a user of services.

- Network-based services quality: The performances providing the managers with controllability network combined of bandwidth, delay, jitter and packet loss to present a network service (voice Over Internetprotocol).

The components of quality of services in WiMAX

IEEE 802.16 standard defines a set of components that are implemented to provide the quality of guaranteed services. Three main components of the quality of services defining in MAC layer in BS as: Connection Admission Control (CAC), scheduler and allocator. These components integrate with PHY layer data but they don’t define the standard of implementation details, this section is used for future technological progress and specific solutions of the vendors [8]. This study is aimed to focus on scheduler component and important algorithms in this regard.

SCHEDULER

Scheduler is the main component layer MAC and it guarantees quality of services for some types of services. This component can be organized as queues in scheduling algorithms. Scheduling queues are used to classify resources in servicing classes defined in IEEE 802.16. The resources are different in terms of transmission type. In DL transmission, scheduler acts in the users data queues and in UL transmission, it is for the queues requiring MS bandwidth. As is shown in Figure 1 [9], scheduling algorithm can be organized based on DL and UL transmission and find about their important role in improving quality of services in WiMAX.

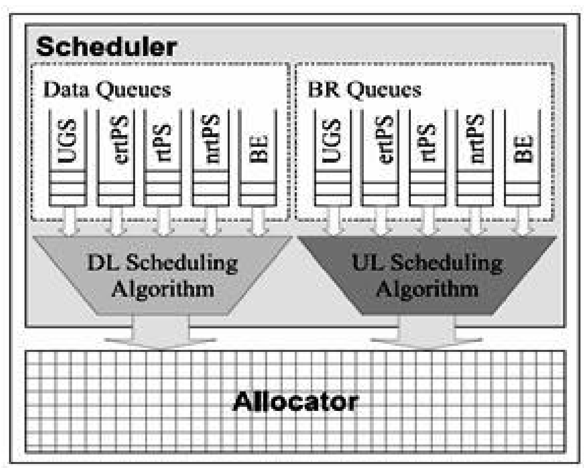

Figure 1: Scheduler component

The priority of the quality of services and designing scheduling in Wi MAX

IEEE 802.16 standard includes the quality of services mechanism in media access control layer architecture (MAC). This standard defines the service flow providing the IP-based services quality. MAC layer is responsible for bandwidth scheduling for various users in accordance to the requirements and quality of services pro files [9]. The standard supports wide range of applications. It is possible, they need different levels of quality of services. IEEE 802.16 standard in accordance to these applications define five servicing flow classes including: UGS, ertPS, rtPS, nrtPS and BE. Later, these classes and assigning them to scheduling algorithms are explained.

UGS and ertPS service-providing classes have similar real-time requirements as the minimum jitter. For example, VoIP transmissions without silence suppression are good for UGS service and VoIP transmissions with silence suppression are good for ertPS service. Thus, we can use similar scheduling factor for both servicing classes. rtPSservicing class has specific quality of services requirements as low delay and high throughput for applications. For example, in video transmission, scheduling factor is defined separately.

nrtPS and BE service classes have no or lowest guarantee of quality of services requirements like the minimum reserved traffic rate. Thus, two servicing classes can apply similar scheduling algorithm.

Various applications with different priorities are classified by scheduler in accordance with their quality of services class in the designed network as UGS<rtPS<nrtPS<BE .

SCHEDULING ALGORITHMS IN WIMAX

Scheduling data packet is competition resolution process of bandwidth. A scheduling algorithm should decide about the bandwidth allocation among the users and their delivery orders. One of the most important goals of scheduling scheme is as it applies available bandwidth, it can fulfill the quality of services requirements of the users [10]. Some scheduling algorithms regarding MAC layer in IEEE 802.16 and physical layer of modulation of Orthogonal frequency-division multiplexing (OFDM)[11]. IEEE 802.16 standard doesn't specifythe scheduling algorithm to be used. Vendors and operators have their choice among many existing scheduling techniques or they can develop their own scheduling algorithms. Some of the existing algorithms are as:

First-In-First-Out (FIFO)

FIFO is the simplest scheduling algorithm [4]. The data packets enter from all the entrance links to a queuing of stack of FIFO memory and they exist the queue one by one to the exist link. Thus, this algorithm easily queues the process in terms of their entrance order. As context switch is occurred only during process end and there is no need to re-organizing in queuing process, the scheduling overhead is minimum. This queuing needs low calculation and its behavior is predicted. In other words, packet delay is directly dependent upon queue size. The maximum queue size is 10 packets in this project. There are various unsuitable features in the queuing process (due to its simple nature) including:

- As all the packets entered a queue, it is impossible to present various services for different classes.
- If there is a burst of inflow, it is possible the entire buffer is filled and the services are not transmitted to other flows until the services buffer is not emptied.

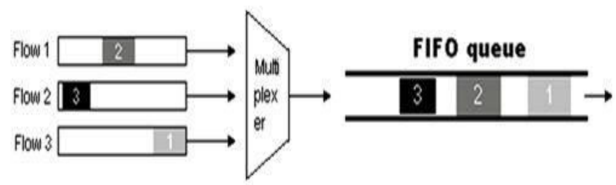

Figure 2: Queuing FIFO algorithm

Priority queue (PQ)

One of the simple methods of presenting various services to different classes of packets is priority queuing. This method is including the classification of each of the entrant packets to various priorities and their establishment inside the separate queues (based on related priorities) in accordance to Figure 3 [12].The packets with highest priority are sent to the exist more than the packets with low priority. Although queuing is a good method to provide various services, it has some shortcomings. Because the big flows enter high priority entering the queue and lead to unallowable delay and it is possible the services are not dedicated to the packets with low priority [13]. This performance leads to scarcity for the quality of service classes with low priority.

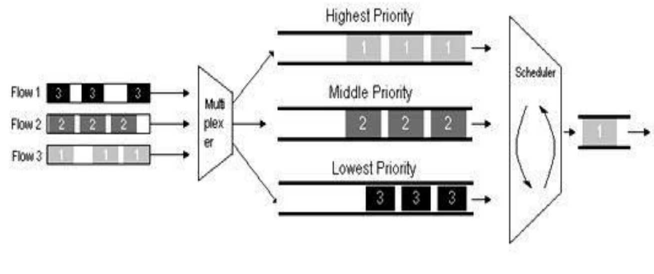

Figure 3: Priority queuing

Weight Fair Queuing (WFQ)

WFQ is also called "Round Robin bit" as its scheduling and queuing performance is based on the bits not the packets. WFQ is informed of the packets size and can support the packets with varied sizes [14]. This technique is obtained of extending fair queuing (FQ) supporting the flows with different bandwidth requirements. A WRR algorithm assigns weight to each queue and the bandwidth is then allocated according to the weights. The WFQ weights can be used to adjust for the quality of services control dynamically, for example to achieve the guaranteed data rate. WFQ allocates different weight to any flow to have different bandwidth percent to avoid exclusion of bandwidth by some flows and to achieve fair scheduling for various flows. The weights can be formed based on some parameters. In addition to queue length and packet delay, the bandwidth size can determine the queue weight (the bigger the size, the more the bandwidth). For example, the minimum reserved traffic rate is considered as a weight. A view of this algorithm is shown in Figure 4.

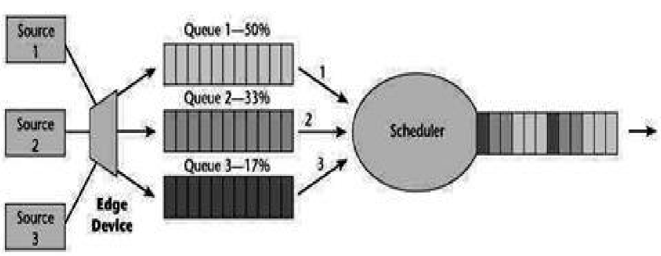

Figure 4: WFQ scheduling

Round Robine (RR)

They are the simplest scheduling algorithms designed specifically for time sharing systems. The RR algorithm can be considered the very first simple RR and it fairly assigns allocation one by one to all connections. With packet-based allocation, stations with larger packets have an unfair advantage. In addition, RR may be non-work conserving in the sense that the allocation is still made for connections that may have nothing to transfer; since RR cannot assure quality of servicesfor different service classes [5].

Deficit Round Robin (DRR)

DRR was proposed by M. Shreedhar and G. Varghese in 1995 [4]. It can handle packets of variable size without knowing their mean size. In this method, a number is selected as quantum and thenit is subtracted from the packet length, and packets that exceed that number are held back until the next visit of the scheduler.Fair queuing is used to allocate the classes to the queues. DRR is used with a share of service connected to each queue (byte) to service the queues. The only difference from RR is that if a queue was not able to send a packet in the previous round because its packet size was too large, the remainder from the previous quantum is added to the quantum for the next round. Thus; queues that were not serviced in a round are compensated in the next round.When a flow was serviced, without considering weight, this flow should wait for the servicing of the rest of flows before being re-serviced. A flow can consume all its quantum in each round completely. Thus, DRR has low delay. A view of this algorithm is shown in Figure 5.

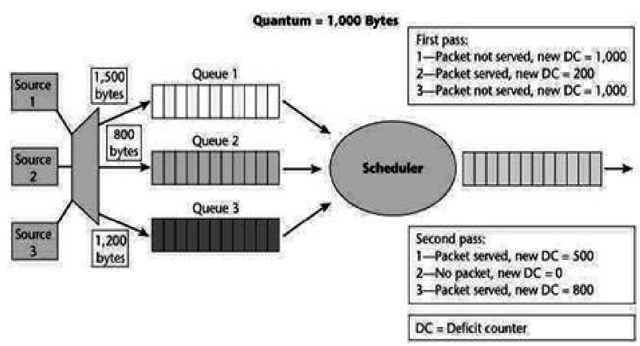

Figure 5: DRR scheduling algorithm

Modified Deficit Round Robin (MDRR)

MDRR scheduling is an extension of DRR scheduling scheme. This algorithm is mostly based on DRR scheduling bases and in MDRR, the value of data allocated for the queues is based on their weight. MDRR scheduling scheme considers a priority queue with DRR. A priority queue scheme separates critical flows from the rest of flows to present the better quality of services and there are two MDRR schemes [4].

a. Alternative mode

In this mode, the queues with high priority are serviced among other queues.

b. Strict priority

The queue with high priority and congestion is serviced and when all the packets of the queue were sent, the other queues are serviced. When there is any congestion in the high priority queue, the scheduler services the packets and returns to the queue with high priority.

SIMULATION AND ANALYSIS MODEL

Evaluation method

The general goal of this paper is the analysis of the performance of various scheduling algorithms in WiMAX environment and their correct application in various applications to improve quality of services. Simulation is done by OPNET 14.5. Generally, there are three methods to evaluate a scheduling algorithm:

Deterministic modeling: A deterministic modeling has no stochastic phenomenon influencing the future modes in the system and always there is a similar output of the initial mode.

Queue models: In this modeling, stochastic queuing are studied analytical by mathematical method as using Markov or Poisson methods.

Implementation/Simulation: The most dynamic test of scheduling algorithms is simulating the algorithm designed by real conditions.

Although common software as C,C++, Java and MATLAB and other programming languages are strong, these programming languages are not with a model of specific system. Thus, OPNET is the best choice among the simulators in terms of support and precision of the classes and protocols of WiMAX network and data analysis and various outputs [4]. This is a Discrete Event Simulation (DES) and the events are considered based on time order.

System modeling

To study the performance of various scheduling algorithms, a scenario is simulated with three cells including a basic station and 8 mobile stations by OPNET software in 4*8 km space. This is shown in Figure 5-2.

The network traffic is produced via three servers explained in traffic model and it is transmitted via a router to three basic stations. These BSs support all the servicing classes in MAC layer and prioritize the received traffics of the users based on the service type and suitable service class in each cell and this is explained in the quality of services model. Some adjustments are made in accordance to the quality of services for mobile nodes, basic station and WiMAX configuration node and the details are shown in Tables 5-1 to 5-3. WiMAX configuration node is used to store PHY profiles and servicing classes that are visited by all WiMAX nodes.

Quality of services model

QoS configuration node defines the details of QoS configuration for the protocols supported in IP layer. ToS is used in adjusting QoS node and priority is based on servicing classes not the parameters as protocol, port and etc. This indicator is used to define the packets class in IPv4 header as shown in Figure 5-1.Precedence (PREC) is consisting of three bits indicating the packet type in terms of importance, priority of servicing in IPv4 datagram. It means that we can define 8 classes and here we used 4 classes to improve QoS. For example, zero indicates the packet is ordinary and it is used for BE(0) class. The D,T,R bits define the servicing manner of the packet. D indicates low delay, T high throughput and R high reliability. Four classification schemes are used in Table 5-4 in ToS to create fairness and improvement of QoS. The priority of these applications starts from the highest in start and lowest in web browser. For better simulation of the network and obtaining the QoScorresponding the various applications, three classes of Gold, Silver and Bronz are formed in accordance to Table 5-5. Gold class is equal to UGS scheduling classes, silver class with nrtPS scheduling class and Bronze class in accordance with BE scheduling class. Finally mapping of servicing classes to ToS is done in basic WiMAX station as shown in Table 1.

Table 1: ToS field structure in IP V4 packet header

PREC	D	T	R	NOPP

Traffic model

In this simulation, three traffic sources are implemented by three various servers and these traffics are sent via central router for three BSs and then are given to the users of each cell via downlink paths. Each mobile station in each cell is put in one of the servicing classes by BS based on its application.

The traffic characteristics of the classes are shown in Table 5-4.

The voice traffic and video conference model

Audio and visual components have different bandwidth requirements. The voice component requires fixed bandwidth 64 kb/s and the image requires bandwidth ranging 512 to 1024 kb/s. VoIP traffic with GSM coding and a voice frame in each packet ,Interactive Voice(6)ToS and UGS servicing class are used in this simulation. For video traffic, Video Conferencing (Light) with time series 15 frames/s and frame size 120*128 pixel, Interactive Multimedia(5)ToS and rtPS servicing class are used.

Web traffic model

Web traffic model is used for BE class. Each web page is including some objects including the images, light pages, Applets of Java, plug-in and the page. Web Browsing (Heavy) with class Best Effort(0)ToS is used in simulation of this traffic.

FTP traffic model

File Transfer (Heavy) traffic model is used for nrtPS servicing class that is a traffic generation FTP with fixed data packet as 50000 byte and ToS standard (2) class is used. This traffic is produced by group 2 server and is transmitted to all BSs via router.

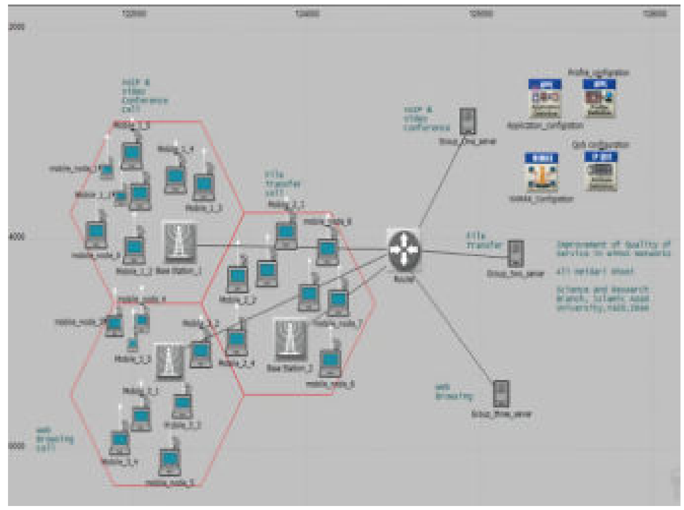

Figure 6: A view of simulated network

Table 2: The characteristics of mobile station (MS)

Characteristics	Values
Trajectory	Vector
Antenna gain (dBi)	-1dBi
Maximum transmission power	0.5w
Physical profile	Wireless OFDMA 20MHz
Multi-path channel model	ITU Vehicular A
Path loss model	Vehicular
Ranging power step	0.25 mw
Propagation model	CCIR
Modulation and coding	Adaptive
Bandwidth request	Piggyback

Table 3: The characteristics of WiMAX basic station (BS)

Characteristics	Values
Antenna gain	15dBi
Number of transmitters	STC 2*1 MIMO
Physical profile	Wireless OFDM 20 MHz
Maximum transmission power	0.5 w

Table 4: The characteristics of WiMAX network (PHY)

Characteristics	Values
Duplexing technique	TDD
Channel bandwidth	20 MHz
Channel frequency	5 GHz
Maximum transmission power	0.5w
Frame duration	5ms
Number of subcarriers	2048

Table 5: Classification of ToS classes in QoS nodes

Application	Traffic characteristics		The values of PREC-D-T-R in ToS field
VoIP	InteractiveVoice(6)	IP ToS	110100
Video Conference	InteractiveMultimedia(5)	IP ToS	101110
FTP	Standard(2)	IP ToS	010011
HTTP	Best Effort(0)	IP ToS	000001

Table 6: The characteristics of servicing classes and traffic parameters (MAC layer)

The name of servicing class	The type of servicing class	Maximum Sustain Traffic Rate(MSTR) (Kbps)	Minimum Reserved Traffic Rate (MRTR) (Kbps)	Maximum Latency (ML)
Gold	UGS	64	64	15 ms
Gold	rtPS	1024	512	20 ms
Silver	nrtPS	512	384	30 ms
Bronze	BE	384	64	30 ms

Table 7: The mapping of servicing classes to ToS classes

Application	Servicing classes	SAP type	Traffic characteristics	
VoIP	Gold	IP	InteractiveVoice(6)	IP ToS
Video Conference	Gold	IP	InteractiveMultimedia(5)	IP ToS
FTP	Silver	IP	Standard(2)	IP ToS
HTTP	Bronze	IP	Best Effort(0)	IP ToS

Launching simulation

Simulation is performed by various scheduling algorithms including FIFO, WFQ, PQ and MDRR on the scenarios to transmit data, voice and image in WiMAX network. Simulation has some results for average jitter, video delay mean, throughput and received traffic for different types of applications in WiMAX network. Some weights are allocated in ToS to applications to improve QoS and these are shown in Tables 5-7 to 5-9, respectively. The results of simulation are shown in figures 5-3 to 5-9.

Table 8: The adjustments of QoS node in priority queue

Application	Priority	Maximum queue size (pkts)	Classification design (ToS)
VoIP	3(High)	500	InteractiveVoice(6)
Video Conference	2(Medium)	500	InteractiveMultimedia(5)
FTP	1(Normal)	500	Standard(2)
HTTP	0(Low)	500	Best Effort(0)

Table 9: The adjustments of QoS node in WFQ queue

Application	Weight	Maximum queue size (pkts)	Classification design (ToS)
VoIP	50	500	InteractiveVoice(6)
Video Conference	35	500	InteractiveMultimedia(5)
FTP	10	500	Standard(2)
HTTP	5	500	Best Effort(0)

Table 10: The adjustments of QoS node in MDRR queue

Application	Weight	Maximum queue size (pkts)	Classification design (ToS)
VoIP	50	500	InteractiveVoice(6)
Video Conference	35	500	InteractiveMultimedia(5)
FTP	10	500	Standard(2)
HTTP	5	500	Best Effort(0)

Figure 7shows that priority queue has the lowest jitter due to strict priority and WFQ due to using suitable weighting. However, FIFO and MDRR scheduling algorithms have highest jitter. The results showed that PQ and WFQ had the minimum jitterand are the best choice for the users using VoIP. Figure 8 indicates the mean end to end delay in video conference traffic. In this figure, PQ,WFQ and MDRR scheduling algorithms have the lowest delay and FIFO scheduling algorithm has the highest delay in this traffic.

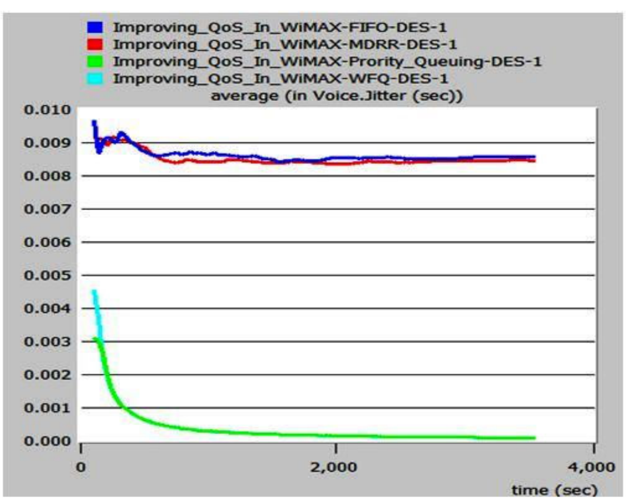

Figure 7: Averagejitter –voice (s)

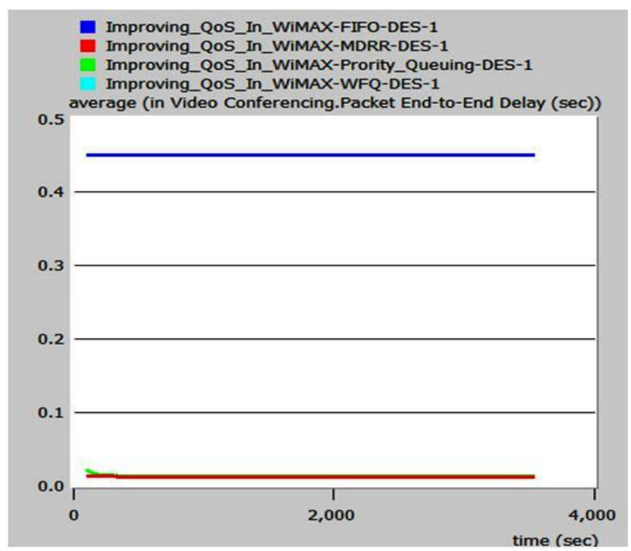

Figure 8: Average video conferencing packet end to end delay (s)

Based on the results in Figure 9, PQ scheduling algorithm and then WFQ have the highest throughput due to using strict priority and good weighting and MDRR and FIFO scheduling algorithm have the lowest throughput in WiMAX network, respectively.

Figure 10 shows voice received traffic (packet/sec) for various scheduling algorithms in VoIP.

Here, the maximum received traffic is dedicated to WFQ scheduling algorithm and then PQ algorithm. Scheduling algorithms MDRR and FIFO have the lowest received traffic for voice.

The maximum received traffic is dedicated to PQ scheduling algorithm for video applications as shown in Figure 11. MDRR and WFQ algorithms have average received traffic and FIFO algorithm has the lowest received traffic. For the users applying similar applications in terms of QoS parameters including FTP and HTTP, as shown in Figures 12 and 13, MDRR algorithm has the best received traffic and FIFO has the lowest received traffic. As the most important QoS parameter in these networks is throughput, MDRR scheduling algorithm is recommended due to having the maximum received traffic.

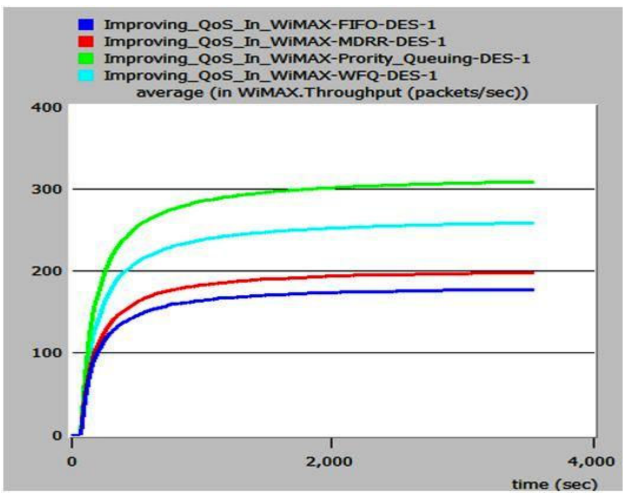

Figure 9: WiMAX network throughput (packets/sec)

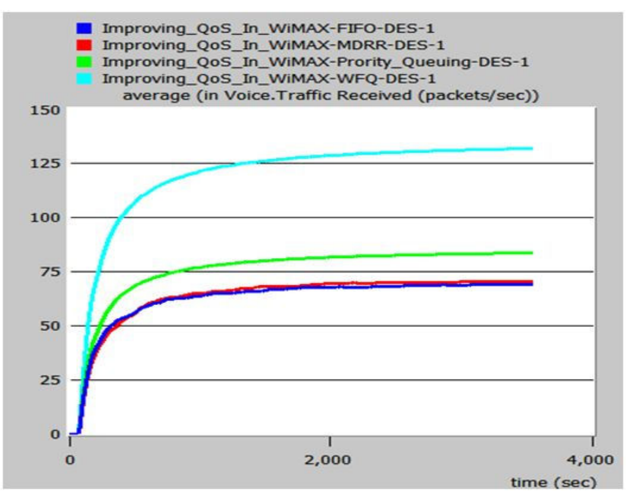

Figure 10: Received traffic in voice (packet/sec)

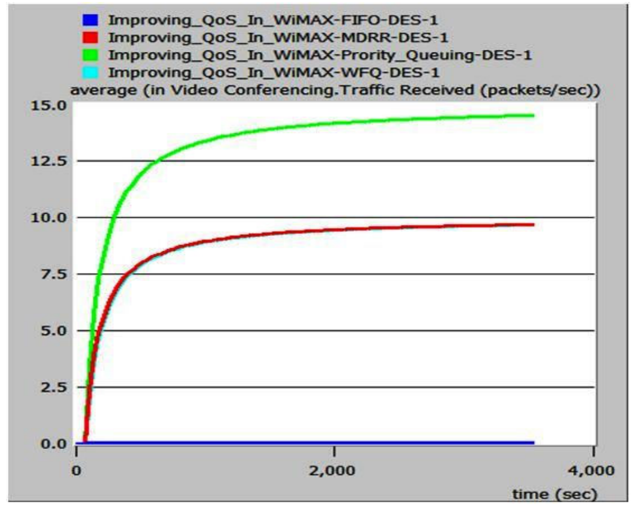

Figure 11: Received traffic in video conferencing (packet/sec)

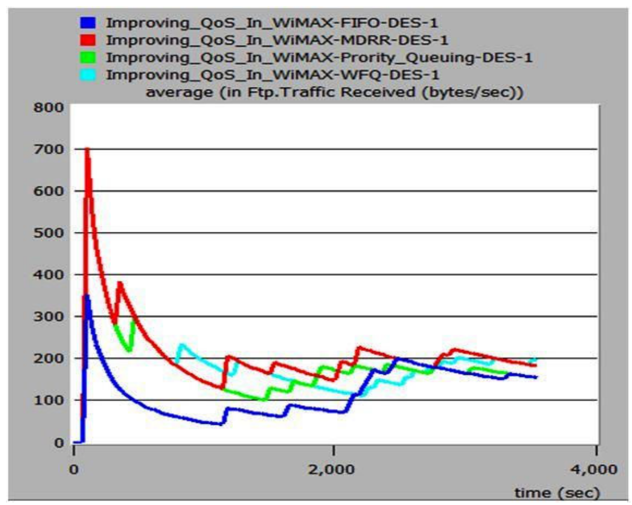

Figure 12: Received traffic FTP (packet/sec)

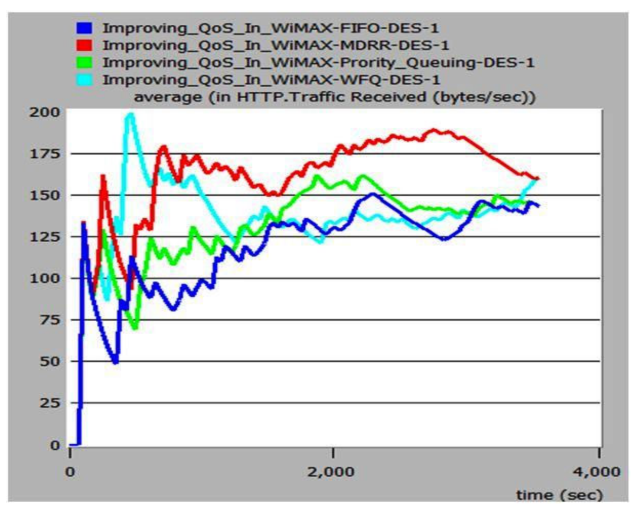

Figure 13: Received traffic HTTP (packet/sec)

CONCLUSION

The study presented a comprehensive performance evaluation of scheduling algorithms in WiMAX networks and investigated the behavior of scheduling algorithms FIFO, WFQ, PQ and MDRR in WiMAX.

Also, the performance of each scheduler is compared in various classes of QoSby various traffic as voice, video conferencing, file transmission and web browsing. As delay changes parameter is the most important factor to improve QoS in these networks in voice networks and based on the simulations results, we can say scheduling algorithms of WFQ priority queue are the best choice to be used in voice traffic among other algorithms due to the lowest delay changes.

Two factors of throughput and delay are the important QoS parameters in these networks in videoconferencing applications and PQ scheduling algorithm is the best algorithm due to the highest received traffic and low delay. Finally, MDRR scheduling algorithm is the best for file sending and web browser in terms of priority of throughput parameter in servicing classesnrtPS and BE belonging to these two groups of traffic and also it is best in terms of maximum traffic.

Based on the simulations, besides using different servicing classes as UGS, rtPS, BE and etc in WiMAX network, these classes alone can not provide QoS in WiMAX network and using various scheduling algorithms plays important role in improving QoS. To introduce a unified scheduling algorithm in WiMAX network for all applications, PQ scheduling algorithm and then WFQ algorithms are proposed.

The present study showed that none of the current algorithms had the capability to create an efficient, faire and strong scheduler to support all WiMAX classes. The analysis and conclusion of the study can be used to perceive the weaknesses and strengths of current scheduling algorithms and the design of efficient scheduling algorithms considering all or some of the weaknesses. For further studies, it is proposed to use simulation to investigate the efficiency of scheduling algorithms aware of delay sensitive algorithms and channels as EDF in WiMAX networks to specify their effect on various applications.

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